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Pisulinella miocenica, a new genus and species of Miocene Neritiliidae (Gastropoda: Neritopsina) from Eniwetok Atoll, Marshall Islands

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Abstract. ***Pisulinella*** **is proposed as a new monotypic genus in the neritopsine family Neritiliidae, with the single species *Pisulinella miocenica* sp. nov. This new taxon occurs in subsurface Miocene sediments from Eniwetok Atoll, Marshall Islands, western Pacific. Nine specimens of *P. miocenica* were previously regarded as close to *Nerita* (*Amphinerita*) *polita* Linnaeus of the Neritidae. Reallocation of this species from Neritidae to Neritiliidae is based mainly on the shape of the protoconch, which is conspicuously tilted relative to the teleoconch whorls and has several spiral ridges. The discovery of this neritiliid species, previously allocated to the Neritidae, suggests that detailed examination of protoconchs is necessary for defining the systematic position of fossil neritopsines. *Pisulinella miocenica* sp. nov. may have lived in a cryptic habitat.**

Key words: Eniwetok, Neritiliidae, *Pisulinella miocenica*, protoconch, submarine cave

Introduction

The gastropod superorder Neritopsina has a fossil record from Silurian to Recent (Tracey *et al.*, 1993). This group underwent major adaptive radiation in the geological past, which has resulted in fairly diverse shell morphology and soft-part anatomy. The early history of neritopsine evolution is unknown, although some suprageneric phylogenies have been proposed for extant groups (e. g. Holthuis, 1995). Bandel (1992) documented the supposed earliest neritopsine from the Ordovician, although it differs greatly in teleoconch morphology from modern relatives. Unconventional species of neritopsines occur even in Recent faunas, such as the bizarre gastropod *Pluviostilla palauensis*, possibly belonging to a new neritopsine group, from a submarine cave in Palau (Kase and Kano, 1999). Additional discoveries such as these may eventually lead to a better understanding of neritopsine evolution.

Neritopsines are usually "neritiform" and tightly coiled, but may also have a limpet-like shape or, rarely, be shell-less (Cox and Knight, 1960; Ponder, 1998). Frequent convergence and parallelism, however, prevent reliable classification of the fossil forms and hinder an understanding of neritopsine evolution. Cox and Knight (1960) recognized 19 fossil genera of Neritidae and diagnosed most genera solely on the basis of general teleoconch shape. These fossil neritopsines must be reexamined to document their more conservative characters, such as shell microstructure, shell muscle scars, and protoconchs, in order to clarify their systematic positions. We describe a new genus and species in the family Neritiliidae from Miocene sediments at Eniwetok Atoll in the Marshall Islands, with special attention being given to protoconch morphology. This new species was once thought to be a modern species of the family Neritidae.

Materials

The nine specimens described here were recovered from three deep subsurface cores drilled by the U. S. Geological Survey in 1951–1952 on Eniwetok Atoll in the Marshall Islands. The drill holes penetrated Recent to upper Eocene sediments, and the cores and cuttings of the drill holes yielded gastropods of remarkably high diversity, which were described by Ladd (1966, 1972, 1977) in his series of monographs on Cenozoic polyplacophorans and gastropods of tropical western Pacific islands. Specimens of the present new species were recovered from cores at depths ranging

from 253 to 298 meters (830 to 978 feet) below the surface and dated as early to late Miocene. See Ladd and Schlanger (1960) and Schlanger (1963) for details of the drilling operations and stratigraphic information.

All specimens used in this study are in the National Museum of Natural History, Washington, D. C. (USNM). SEM examinations were made in a low vacuum mode without a metal coating.

Systematic paleontology

Superorder Neritopsina Cox and Knight, 1960
Family Neritiliidae Schepman, 1908
Genus ***Pisulinella*** gen. nov.

Type species.—*Pisulinella miocenica* sp. nov.

Diagnosis.—Genus similar to *Pisulina*. Inner lip of aperture smooth, convex, bearing three or four inconspicuous teeth at margin; a shallow groove on inner lip callus extends along inner line. Outer lip thick, with a blunt, rounded margin and with weak tubercles along the interior. Protoconch multispiral, inclined; larval shell sculptured with six or seven spiral ridges.

Etymology.—Combination of the neritiliid genus *Pisulina* and *ellus* (Latin: diminutive), referring to the smaller shell similar to *Pisulina*.

Discussion.—Neritiliidae Schepman, 1908 is a distinct family in Neritopsina, but until quite recently it had been thought to be a subfamilial taxon (Neritiliinae) of Neritidae (e. g. Cox and Knight, 1960; Ponder, 1998). Based upon her extensive anatomical study, Holthuis (1995) has clarified the paraphyly of Neritidae, and shown that *Neritilia* (the type genus of Neritiliidae) is the first offshoot in the clade "Neriti dae" + Phenacolepadidae. Recently, Kano and Kase (in press) have reallocated the submarine-cave genus *Pisulina* from Smaragdiinae in Neritidae to Neritiliidae, based on finding 11 synapomorphies of *Pisulina* and *Neritilia* in the anatomical and shell characters.

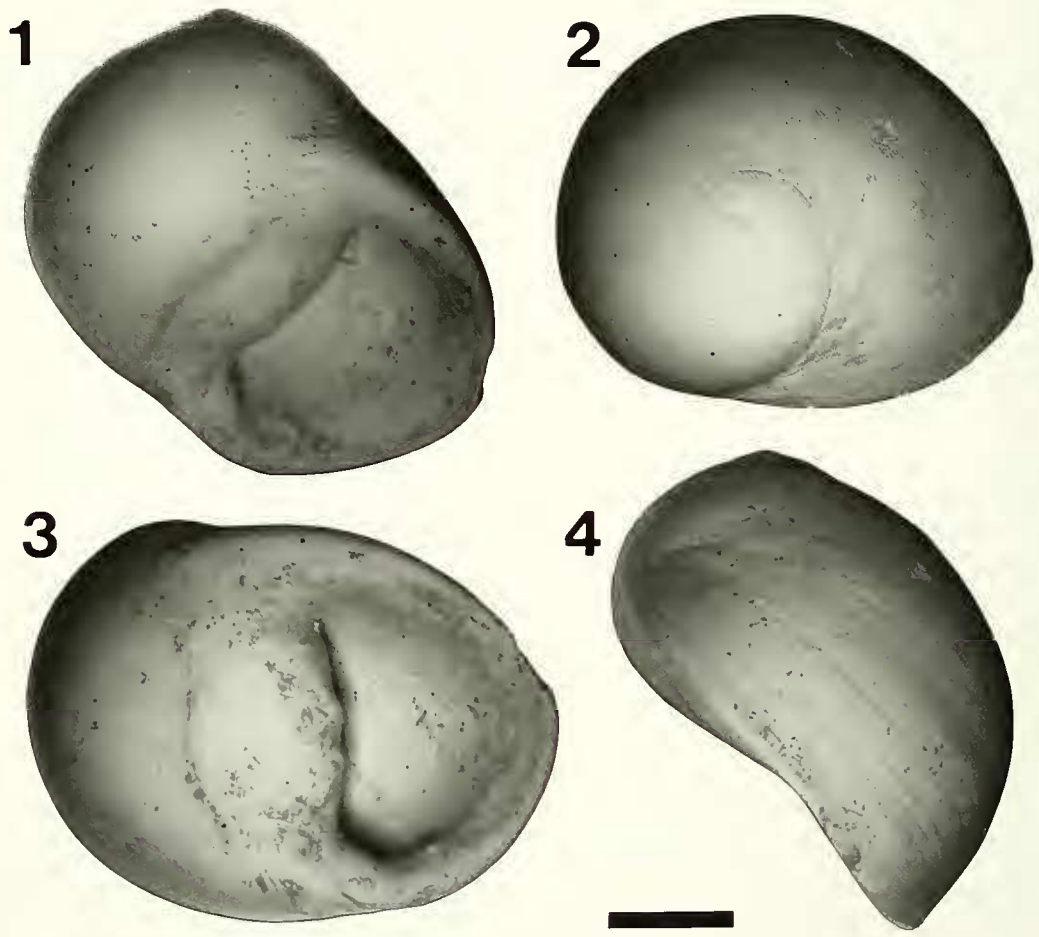

Figure 1. *Pisulinella miocenica* gen. et sp. nov. **1–4.** Front, apical, apertural and lateral views of the holotype (USNM 648333). Scale bar = 1 mm.

The most important shell character for defining the taxonomic position of *Pisulinella* is protoconch morphology. The protoconchs of neritopsine species with planktotrophic development are unique and quite uniform in shape (e. g. Bandel, 1982). The larval shell is oval to globular-naticiform, smooth except for fine growth lines, and coils almost planispirally. Kano and Kase (in press) distinguish Neritiliidae from the other families in the superorder based on the fact that its coiling axis is remarkably tilted compared to that of the teleoconch, and because the protoconch surface bears several spiral ridges near the aperture. *Pisulinella* shares protoconch features with *Pisulina* and *Neritilia*, as described in the systematic part of this report. Although the soft anatomy of *P. miocenica* sp. nov. is not known, the new genus unequivocally belongs to Neritiliidae.

The family Neritiliidae heretofore included the two modern genera *Neritilia* Martens and *Pisulina* Nevill and Nevill (Kano and Kase, in press). *Pisulinella* is related to *Pisulina* rather than to *Neritilia*. *Neritilia rubida*, the type species of the genus, has a thin calcareous layer that covers the embryonic shell (Kano and Kase, in press). Bandel and Riedel (1998, fig. 6A, B) showed another example in a species of the genus from Cebu, Philippines, but the calcareous layer appears to be thinner than that of *N. rubida*. However, this layer is absent in *Pisulina* and *Pisulinella* (this condition in *Pisulina* is typically developed in *P. adamsiana*; see Herbert and Kilburn, 1991, fig. 3). Teleoconch morphology also indicates that *Pisulinella* is close to *Pisulina* rather than to *Neritilia*. In *Pisulinella* and *Pisulina* (particularly *P. adamsiana*), the inner line of the apertural inner lip callus has a reversed S-shape, and the basal lip bears a weak protuberance (Figures 1, 2). On the other hand, *Pisulinella* possesses more numerous spiral ridges on the larval shell, and the exposed area of the embryonic shell is much smaller than in *Pisulina adamsiana*. The apertural morphology is also characteristic of *P. miocenica*. When the shell is fully grown, the outer lip is thickened along its interior with many obscure tubercles, and is blunt and rounded along its margin (Figure 2.1). Furthermore, the inner lip callus of *Pisulinella* has a shallow groove that extends along the inner line (Figure 2.2). None of the species of *Pisulina* and *Neritilia* have such features. We therefore conclude that *Pisulinella* is a distinct genus in Neritiliidae.

Pisulinella miocenica sp. nov.

Figures 1–3

Nerita (*Amphinerita*) aff. *N. polita* Linnaeus: Ladd, 1966, p. 56, pl. 10, figs. 17, 18.

Diagnosis.—As for the genus.

Description.—Shell small, up to 4.0 mm in diameter, 3.7 mm in height (Table 1), thick, solid, obliquely ovate with a low spire, brownish cream in color without color markings (Figure 1). Inner walls of whorls resorbed, producing a hollow cavity inside. Protoconch multispiral, consisting of embryonic and larval shells, deeply immersed in first teleoconch whorl, separated from teleoconch by a clearly demarcated line; protoconch axis inclined significantly relative to teleoconch (Figure 3.1). Embryonic shell largely covered by larval shell and also sometimes by first teleoconch whorl, depending on protoconch inclination, and sculptured with faint, reticulate grooves (Figure 3.2); exposed portion of embryonic shell ca. 60 μm in maximum dimension; larval

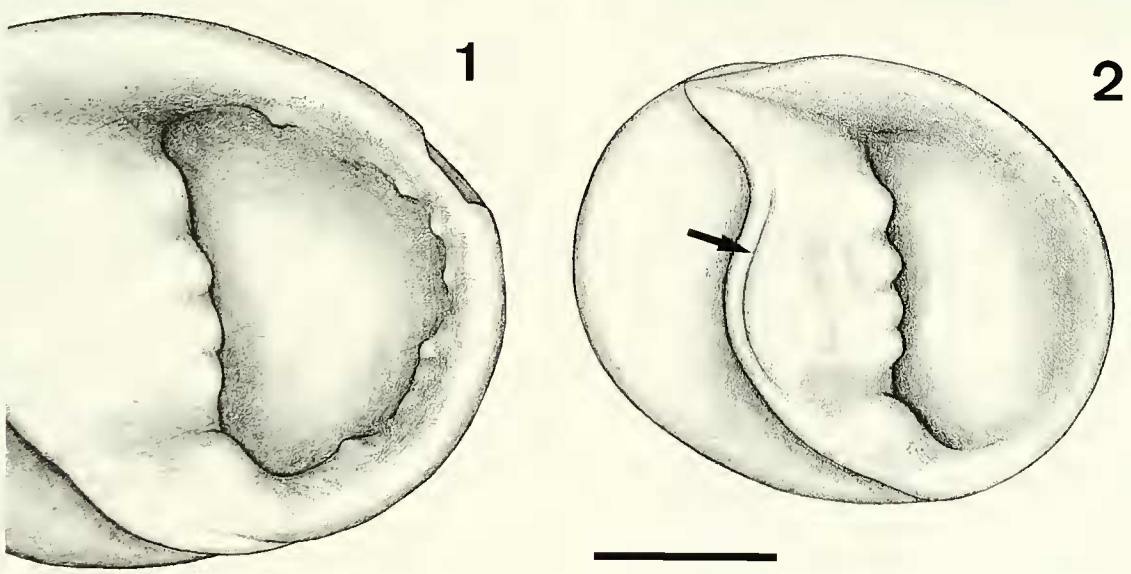

Figure 2. Drawings showing the detail of apertural characteristics in *Pisulinella miocenica* gen. et sp. nov. Scale bar = 1 mm. **1.** Holotype with four teeth along the inner lip, a weak protuberance in the basal lip, and many obscure tubercles on the outer lip. **2.** Paratype 6 (USNM), juvenile shell, with an unornamented outer lip that has a sharp margin. Arrow indicates a shallow groove in the inner lip callus along the inner line.

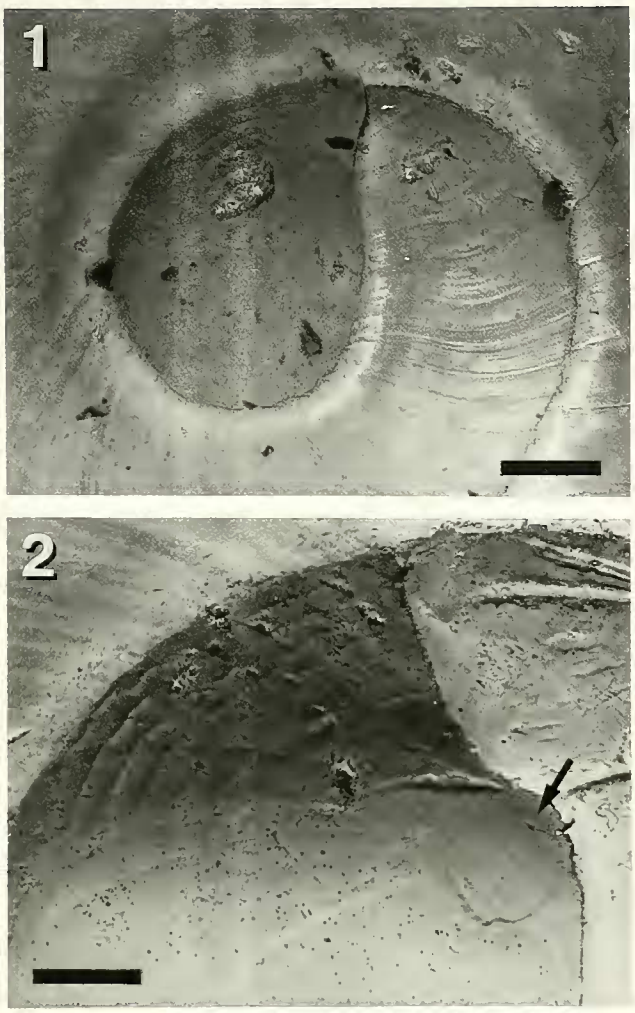

Figure 3. SEM micrographs of the protoconch of *Pisulinella miocenica* gen. et sp. nov. **1.** Apical area of paratype 8 (USNM). Scale bar = 100 µm. **2.** Protoconch of the holotype, showing an exposed embryonic shell (arrow) and seven spiral ridges on the larval shell. Scale bar = 50 µm.

shell surrounded by suture of first teleoconch whorl, and exposed drop-shaped area 295–375 µm in maximum dimensions, sculptured with microscopic pits scattered all over surface, and also with six or seven, ca. 3-µm-wide, up to 200-µm-long spiral ridges near apertural lip. Teleoconch whorls less than 2.3 in number, increase rapidly in size, inflated with a round periphery, slightly concave below sutures; last whorl more or less descending abapically in final growth stage. Suture shallowly impressed. Shell surface smooth, polished, and ornamented with fine growth lines and microscopic, sparse spiral grooves. Aperture widely open and semicircular in outline. Outer lip prosocline, blunt at margin, angled 30° to 40° to shell axis, and thickened along interior with many weak tubercles (Figure 2.1). Inner lip covered with a white, smooth, thick and convex callus; adaxial margin bears 3 or 4 slightly protruding teeth, inner line of callus with a deep and distinct, reverse-S shaped groove surrounding columellar area and continuing to basal lip without sinuation; a shallow groove carved on inner lip callus extends along inner line (Figure 2.2). Basal lip usually bears a weak protuberance. Operculum unknown.

Etymology.—The species name is derived from the word Miocene, the age of the specimens.

Types.—Holotype: USNM 648333, drill hole F-1 at depth of 930–940 feet (283–287 m), Elugelab Island, Eniwetok Atoll, Marshall Islands, lower Miocene (Tertiary *f*). Eight paratypes, USNM, from three drill holes F-1, K-1B, E-1 (on Elugelab Island, Engebi Island, and Parry Island, respectively), Eniwetok Atoll, at a depth of 830–978 feet (253–298 m), lower to upper Miocene (Tertiary *f–g*). See Table 1 for details.

Occurrence.—This species is known only from drill-holes on Eniwetok Atoll, early to late Miocene.

Discussion.—Ladd (1966) assigned this species to *Nerita* (*Amphinerita*) in Neritidae and suggested an affinity to *N.* (*A.*) *polita* Linnaeus, a modern species widely inhabiting the tropical Indo-West Pacific, including the Marshall Islands. However, the present fossil species differs markedly from *N.* (*A.*) *polita* and also from other species of the subgenus in several important ways. The fully grown adult shell of *P. miocenica* is less than 4 mm in maximum diameter (Table

Table 1. Locality and shell measurements of *Pisulinella miocenica* gen. et sp. nov. Paratypes 6–8 are immature specimens and have a sharp margin along their outer lips. The outer lips of paratypes 4 and 5 are largely broken so that the diameters and heights (in parentheses) are not representive of the species.

Specimen	Hole number and depth (feet)	Number of teleoconch whorls	Diameter (mm)	Height	Maximum diameter of protoconch exposed (mm)
Holotype USNM 648333	F-1 (930–940)	2.3	3.8	3.7	375
Paratype 1 USNM	F-1 (920–930)	2.3	4.0	3.4	325
Paratype 2 USNM	F-1 or E-1 (940–950)	2.2	3.7	3.3	335
Paratype 3 USNM	F-1 (900–910)	2.2	3.6	3.3	360
Paratype 4 USNM	E-1 (830–840)	2.2	(2.7)	(2.9)	365
Paratype 5 USNM	F-1 (900–910)	2.1	(2.7)	(3.1)	295
Paratype 6 USNM	K-1B (968–978)	2.0	3.0	2.7	385
Paratype 7 USNM	K-1B (936–946)	1.8	2.8	2.5	340
Paratype 8 USNM	E-1 (900–910)	1.6	2.0	1.9	365

1), while the largest specimen of *N.* (*A.*) *polita* at hand, from Okinawa, Japan, is over 35 mm in maximum diameter. Even the smallest adult of *Nerita* (*Amphinerita*) species at hand is over 15 mm in maximum diameter. Moreover, the shells of *P. miocenica* are plain cream in color and lack the color pattern that is characteristic of *Nerita* (*Amphinerita*). Ladd (1966, p. 11) stated that the fossil shells in the drill-hole section from which this species was recovered apparently never were raised above sea level to be leached and recrystallized. The shells of this new species are almost intact, and many mollusk shells from the same section retain original color patterns (e. g. *Smaragdia* species; see Ladd, 1966, pl. 11, figs. 5–9). These facts strongly suggest that shells of *P. miocenica* were originally plain white, but were subsequently stained brownish cream during fossilization. The presence of a distinct inner line in the callused apertural inner lip, also noted by Ladd (1966), is another character separating *P. miocenica* from *Nerita* (*Amphinerita*) species.

Schlanger (1963) stated that the reef-associated sediments in the drill-hole section from which the shells of *P. miocenica* were recovered were deposited in lagoonal and shore-bank environments. The basis for this belief was the very high content of delicate branching corals and the abundance of large mollusks. Gastropod species associated with *P. miocenica* in the drill holes include a number of microscopic and macroscopic species that also are suggestive of lagoonal and shore-bank environments within a coral reef. Interestingly, however, the plain creamy color of *P. miocenica* suggests a cryptic habitat for this species. Loss of shell color and reduction of shell size are adaptations to gloomy to totally dark cave habitats for mollusks (Kase and Hayami, 1992; Hayami and Kase, 1993, 1996). Four *Pisulina* species found in marine caves are plain white in color and lack color markings (Kano and Kase, in press). Seven species of undescribed neritiliid genera recently found in submarine caves of tropical Pacific islands, and a species of *Neritilia* recently found in anchialine caves (subterranean caves with haline water which have no surface connection to the sea; see Stock *et al.*, 1986), are entirely white (unpublished data). We suggest that *P. miocenica* was a cryptic species that inhabited submarine caves and/or crevices in a coral reef, and that the shells were secondarily transported to an open reef-associated environment by water currents and/or by subsequent destruction of the reef bodies.

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